POWER SYSTEM ANALYSIS II

Activity No. 1

Admittance Matrix Formulation

I. DELIVERABLES

1. Softcopy of source code and required output text files (.txt).
2. Hardcopy of documentation. Submit in A4 paper, IEEE double-column format.
3. Place all files in an encrypted compressed folder (RAR) and upload it at our class e-group with the following filename format: **SURNAME_GROUP#_ACT#** (e.g. CRUZ_GROUP1_ACT1.rar)

II. OBJECTIVES

1. To be able to understand common data format used in solving load flow problems.
2. To be able to use MATLAB or other programming tool/language to read and parse data.
3. To be able to develop a program that will formulate Bus Admittance Matrix.

III. DISCUSSION

- **Formation of Bus Admittance Matrix**

Most power system networks are analyzed by first forming the admittance matrix. The admittance matrix is based upon Kirchhoff's current law (KCL), and it is easily formed and very sparse.

Consider the three-bus network shown in Figure that has five branch impedances and one current source.

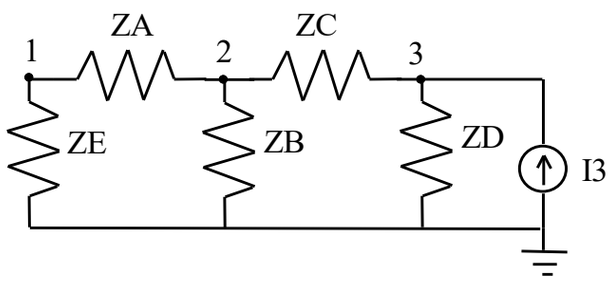

Figure 1. Three-Bus Network

Applying KCL at the three independent nodes yields the following equations for the bus voltages (with respect to ground):

At bus 1, $\frac{V_1}{Z_E}+\frac{V_1-V_2}{Z_A}=0$,

At bus 2, $\frac{V_2}{Z_B}+\frac{V_2-V_1}{Z_A}+\frac{V_2-V_3}{Z_C}=0$,

At bus 3, $\frac{V_3}{Z_D}+\frac{V_3-V_2}{Z_C}=I_3$.

Collecting terms and writing the equations in matrix form yields

$$\begin{bmatrix} \frac{1}{Z_E}+\frac{1}{Z_A} & -\frac{1}{Z_A} & 0 \\ -\frac{1}{Z_A} & \frac{1}{Z_A}+\frac{1}{Z_B}+\frac{1}{Z_C} & -\frac{1}{Z_C} \\ 0 & -\frac{1}{Z_C} & \frac{1}{Z_C}+\frac{1}{Z_D} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ I_3 \end{bmatrix},$$

or in matrix form,

$$YV = I \ ,$$

where *Y* is the admittance matrix, *V* is a vector of bus voltages (with respect to ground), and *I* is a vector of current injections.

Voltage sources, if present, can be converted to current sources using the usual network rules. If a bus has a zero-impedance voltage source attached to it, then the bus voltage is already known, and the dimension of the problem is reduced by one.

A simple observation of the structure of the above admittance matrix leads to the following rule for building *Y*:

1. The diagonal terms of Y contain the sum of all branch admittances connected directly to the corresponding bus.

$$Y_{ii} = \sum_{j=0}^{n} y_{ij} \quad j \neq i$$

2. The off-diagonal elements of *Y* contain the negative sum of all branch admittances connected directly between the corresponding busses.

$$Y_{ij} = Y_{ji} = -y_{ij}$$

- **Modeling of Tap changers**

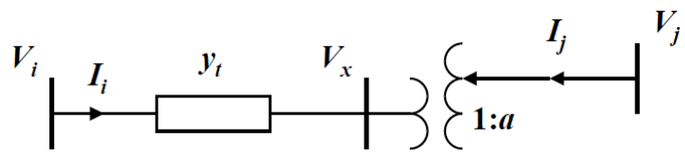

Figure 1. Tap changer connection

This is valid for real values of **a.** Taking the y-bus formation, break the diagonal elements into two components:

- the off-diagonal element represent the impedance across the two buses.
- the remainder form the shunt element.

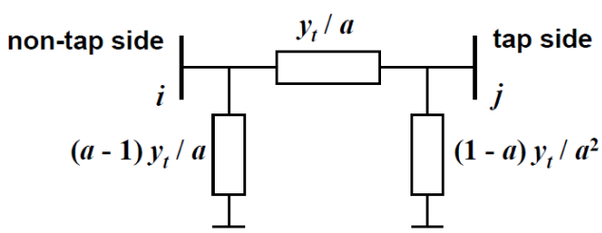

Figure 2. Equivalent model for Tap changers

Sample input data:

Table 1. Bus data

Bus	Type	Vsp	theta	PGi	QGi	PLi	QLi	Qmin	Qmax
1	1	1.040	0	0.0	0.0	0.0	0.0	0.0	0.0
2	2	1.010	0	3.0	88.0	0.0	-0.8	50.0	-17.0
3	2	0.985	0	41.0	21.0	40.0	-1.0	60.0	-10.0
4	3	1.000	0	0.0	0.0	0.0	0.0	0.0	0.0
5	3	1.000	0	13.0	4.0	0.0	0.0	0.0	0.0
6	2	0.980	0	75.0	2.0	0.0	0.8	25.0	-8.0
7	3	1.000	0	0.0	0.0	0.0	0.0	0.0	0.0
8	2	1.005	0	150.0	22.0	450.0	62.1	200.0	-140.0
9	2	0.980	0	121.0	26.0	0.0	2.2	9.0	-3.0
10	3	1.000	0	5.0	2.0	0.0	0.0	0.0	0.0
11	3	1.000	0	0.0	0.0	0.0	0.0	0.0	0.0
12	2	1.015	0	377.0	24.0	310.0	128.5	155.0	-150.0
13	3	1.000	0	18.0	2.3	0.0	0.0	0.0	0.0
14	3	1.000	0	10.5	5.3	0.0	0.0	0.0	0.0
15	3	1.000	0	22.0	5.0	0.0	0.0	0.0	0.0
16	3	1.000	0	43.0	3.0	0.0	0.0	0.0	0.0

(succeeding data are intentionally deleted)

Table 2. Line data

From Bus	To Bus	R pu	X pu	B/2 pu	X'mer TAP (a)
1	2	0.0083	0.0280	0.0645	1
2	3	0.0298	0.0850	0.0409	1
3	4	0.0112	0.0366	0.0190	1
4	5	0.0625	0.1320	0.0129	1
4	6	0.0430	0.1480	0.0174	1
6	7	0.0200	0.1020	0.0138	1
6	8	0.0339	0.1730	0.0235	1
8	9	0.0099	0.0505	0.0274	1
9	10	0.0369	0.1679	0.0220	1
9	11	0.0258	0.0848	0.0109	1
9	12	0.0648	0.2950	0.0386	1
9	13	0.0481	0.1580	0.0203	1
13	14	0.0132	0.0434	0.0055	1
13	15	0.0269	0.0869	0.0115	1
1	15	0.0178	0.0910	0.0494	1
1	16	0.0454	0.2060	0.0273	1

(succeeding data are intentionally deleted)

IV. PROBLEM SPECIFICATION

1. The input text files should follow the format shown below.
2. The high-level programming language Matlab can be used but not limited to other programming language such as C/C++, Java, Visual Basic/C++, etc..
3. The documentation should include but not limited to the following sections.
   i. **Abstract** – brief summary of the problem and your program
   ii. **Implementation** – include a short description of each program module/part
   iii. **Testing** – emphasize all assumptions you made in your program.
   iv. **Results and Discussion**
   v. **Conclusions** – answer the problem objectives
   vi. On the first page/cover page of your documentation, write the boxed statement below (or any statement of the same effect) and sign.

We certify upon our honor that we solved this activity independently, without asking help from anybody. We may have, however, consulted published references and reading materials, and we hereby acknowledge (write proper bibliography) them accordingly. It took us _____ hours to finish this activity.

_____ _____

Sign over printed name Sign over printed name

V. **DISCUSSION**

1. What programming language/tool did you use in this activity and why?
2. Where you able to meet all objectives of this activity? State all the challenges you have encountered in this activity and discuss how you come up with the solutions.